# DECLARATION OF DR. CHARLES L. JACKSON

## I. INTRODUCTION

1. I have been asked by Verizon to describe how a dial-up Internet connection is established, how information flows over such a connection, and where an end-to-end Internet connection terminates, as the term *Internet connection* is commonly understood from an engineering perspective.

## II. QUALIFICATIONS

2. My name is Charles L. Jackson. I received my undergraduate degree in applied mathematics, with honors, from Harvard College in 1966. I received an M.S. in electrical engineering from the Massachusetts Institute of Technology (MIT) in 1974 and a Ph.D. in electrical engineering from MIT in 1977. I have worked for more than 30 years in the electronics and communications industries.

## III. SUMMARY AND CONCLUSIONS

3. I describe how an Internet connection is made using a dial-up telephone connection and how that connection compares to voice calls made over the traditional telephone network. An Internet connection begins in the user's computer, passes through the switched telephone network, is handed off to an Internet service provider (ISP), is then routed around the country (and often around the world), and typically terminates at a distant location on a computer server. Connecting to a web site is a single end-to-end communication.

## IV. VOICE TELEPHONE CALLS AND INTERNET COMMUNICATIONS

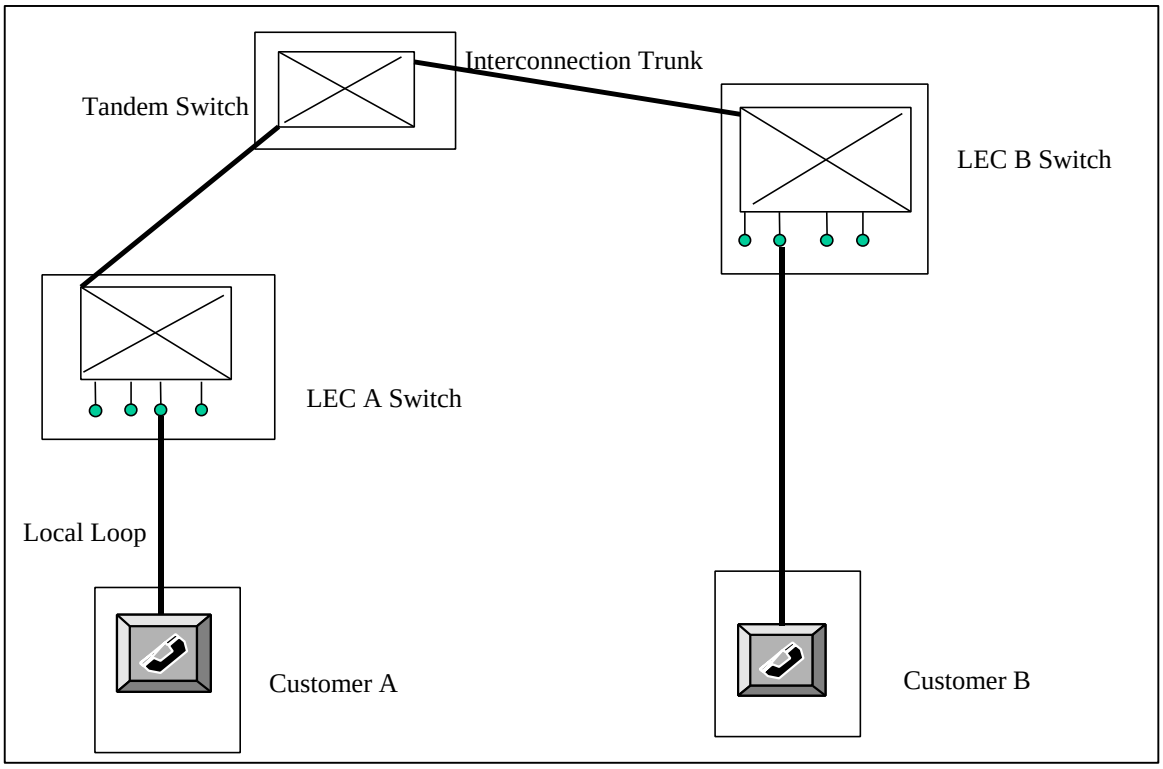
4. Before explaining how a dial-up Internet connection works, I describe how a plain old telephone service (POTS) voice call is placed on a local exchange network. An understanding of the latter provides an appropriate benchmark for comparison.

## A. Voice Calls

### 1. Communication Process

5. When a subscriber makes a local voice call, the subscriber picks up the telephone and dials a telephone number. A pair of wires, or local loop, runs from the subscriber's telephone to a local exchange carrier's (LEC) local switch and carries those dialed numbers to the switch. The local switch uses the numbers dialed to set up a connection or complete a "circuit" between the calling and called parties and rings the called party's telephone. The circuit between the two parties begins with the telephone of the calling party, travels across the calling party's local loop to the central office, and then moves to the local switch of the calling party's local telephone company. From there, the call is routed through the local switch that serves the called party, across the called party's local loop, and to the calling party's telephone. If different local exchange carriers serve the two parties, the call is switched to an interconnection point where the call is handed off to the called party's local exchange carrier. Figure 1 shows the network architecture used in a typical local voice call that flows between two LECs.

**FIGURE 1. A LOCAL VOICE CALL BETWEEN LOCAL CUSTOMERS OF TWO LECS**




6. In this example, the call terminates or ends on LEC B's local network at the premises of the called party, and the end-to-end connection allows customers A and B to communicate with one another.

### 2. Properties of a Voice Call

7. In a typical voice telephone call, voice communications are translated from analog to digital signals and back. The communication starts off as sound waves in the air and is converted to an analog electrical signal by the typical voice telephone. Usually, it is translated into a digital signal at the local switch, is switched in this digital form, is transmitted to other switches in this digital form, and is translated back into an electrical analog signal for termination at the called party's analog telephone where it is converted into sound waves and transmitted to the ear. The form of the digital transmission of the information may also change during the course of the

communication. For example, if the communication passes over fiber optic interoffice trunks or the long-distance network, the information is converted to light waves for optic transmission. The format of the information or the medium of transmission may change, but the underlying communication does not terminate until it reaches the called party. The end-to-end communication does not terminate simply by virtue of being translated into a different signal format.

8. Similarly, voice traffic originating on a cellular network may be translated into a number of different formats before it terminates at its ultimate destination. However, this does not change the fact that the communication does not terminate until it reaches the called party. For example, suppose a Verizon digital cellular customer in Washington wanted to call her or his parents in California. When the voice of the cellular subscriber enters the mobile phone, each fragment of $1/50^{th}$ of a second of speech (requiring about 1,200 bits to represent it in the digital coding most often used in the telephone industry) is transformed, by extensive numerical processing, into a compressed form requiring only about 200 bits to represent the speech fragment. This compressed speech signal is then transmitted by radio to the cellular system. The cellular system transforms this signal from the compressed representation to the standard digital representation used to carry voice telephone calls. From there the signal is likely to be converted into a digitally modulated light wave for transmission over the long-distance network to California where the signal is converted back to analog format for termination on the phone of the cellular customer's parents. Again, the fact that the digital format of the signal is converted several times does not imply that the communication is terminated at each conversion. The end-to-end communication is between the caller in Washington and the caller's parents in California.

9. Likewise, there are a number of instances in which voice telephone calls may be answered, routed, or processed locally before they are sent on to their ultimate terminating destination. Perhaps the most common of these examples involves the use of calling cards to make long-distance calls. When a customer wants to make a

long-distance call using a WorldCom calling card—again, say, from Washington to California—that customer goes through the following steps: (1) the caller dials WorldCom's 800 number 1-800-741-7200; (2) the caller listens for the WorldCom brand and dialing prompt, (3) at the prompt, the caller dials the called number in California and listens for the next prompt; (4) the caller enters the 14 digits of the calling card number and pin; (5) the phone rings, the calling party answers, and conversation occurs.

10. The caller does not generally know what occurs behind the scenes. When the caller reaches WorldCom's 800 number, the call is "answered" by WorldCom in the sense that answer supervision is returned and an initial connection is established. The calling card service provider, here WorldCom, then prompts the caller to dial the second number, allowing the caller to dial the desired number in California. The call is then connected through to the desired number in California where it terminates. Once the conversation is completed, the caller also has the option of pressing the # sign and dialing in a second number in, say, Seattle, Washington. This same option can be used to make a third, fourth, or fifth call, and so on. Despite the fact that answer supervision is returned and an initial connection to the calling card provider is established, there is no question that the end-to-end communication is between Washington and California and that the call terminates in California or another location to which a call is placed.[1]

[1] The calling card example in the text above is merely illustrative; there are numerous other examples. Long-distance calls placed using PBXs offer another example of this phenomenon. A PBX can be programmed to allow a user to dial in, receive a prompt, and then dial the number to which he or she wishes to be connected. Answer supervision is returned when the PBX generates the prompt, but the call does not terminate at the PBX—rather the call terminates at the ultimate destination. Still another example is a form of exchange access known as Feature Group A that was used by MCI at the time of the breakup of AT&T. Under this arrangement, a customer first dialed a seven-digit telephone number, received a second dial tone, and then dialed the phone number of the person he or she wanted to reach. Again, the end-to-end call terminated at its ultimate destination, not at the initial connection to MCI's network.

## B. Dial-up Internet Connections

### 1. Communication Process

11. When a dial-up customer connects to the Internet, these connections typically are routed around the country (and often around the world) and finally terminate at a distant location on a web site server.[2] For the purposes of consistency, I again consider the case in which such a call travels across two LECs on the originating end when describing the path of communication. In the Internet case, the call, or "communication," originates when a customer uses a computer modem to connect to the Internet service provider (ISP), which then connects the customer on through to the rest of the Internet. Consider a now-familiar case—a user browsing the World Wide Web. The communication starts at the computer keyboard when the customer activates the browser and instructs it to establish an Internet connection. The browser then activates software that instructs the customer's modem to connect to the ISP, typically by dialing either a 7- or 10- digit telephone number or an 800 number. The customer then designates the desired Web site by clicking on an icon or typing an address designator or uniform resource location (URL) into the browser.[3] The browser repackages the request for the web site into the form that is understood by web servers and passes that request on to other software in the computer, which repackages it as a packet of information and sends the packet of information to the computer's modem.

12. The customer's modem transforms the data, the ones and zeros in the packet, into a form that can travel well over a telephone line and sends that data out over the telephone line. The packet travels across the local loop to LEC A's local switch in the central office, is handed off to LEC B that serves the customer's ISP, and is routed by LEC B to the ISP.[4] At the ISP's location, the signal from the telephone line

---

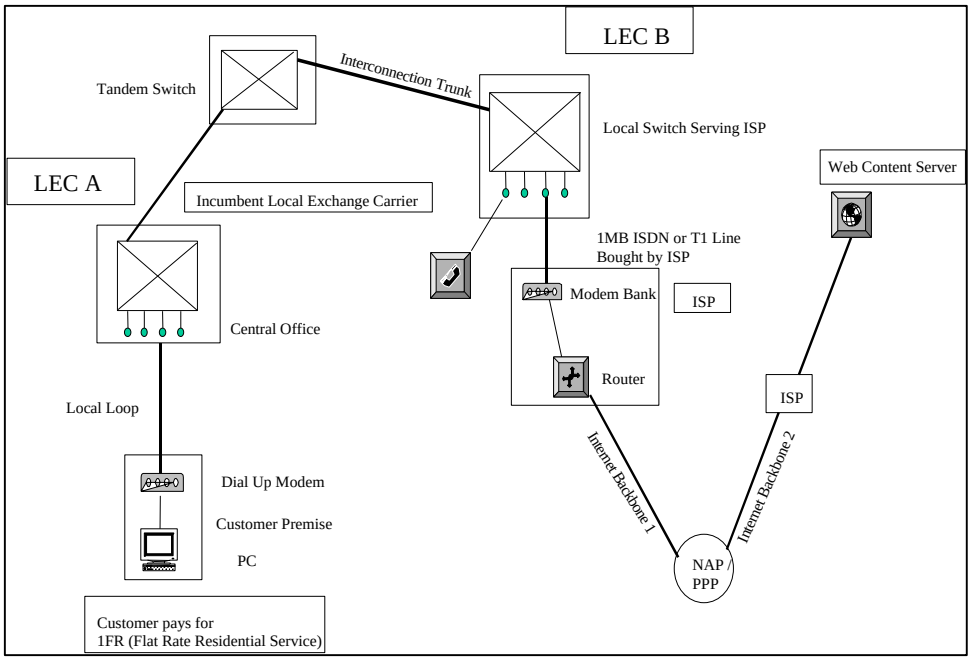
[2] Dial-up access to the Internet occurs when a customer uses a PC modem to connect to an ISP's modem over a normal analog telephone line. Dial-up access is the most common method of accessing the Internet by residential users.

[3] A uniform resource locator is the set of characters you type into your browser to visit a location on the Internet (such as www.ESPN.com). Conceptually a URL can be thought of as an Internet address.

[4] ISPs buy phone lines from their local exchange carriers that they connect to their modem banks to provide dial-up access to their local customers.

is routed to a modem where it is transformed from a form that travels well over a voice telephone connection to a simpler form of ones and zeros better suited for computer processing. A switch at the ISP's location (called a router) examines the address information in the packet and sends the packet off on the proper route. The packet is sent off via a high-capacity digital connection to the Internet backbone where it is transported and routed to its final Internet destination. After it hits the first backbone, the communication is likely to be routed to one or more additional backbones that interconnect with each other at public network access points (NAPs) or private peering points (PPPs) until it is routed to an ISP serving a computer that hosts the web site being requested, and ultimately terminates at the desired web site. Figure 2 shows network architecture used in a typical dial-up Internet communication when two LECs are involved on the originating end.

**FIGURE 2: ILEC SUBSCRIBER MAKING DIAL-UP CONNECTION TO ISP SERVED BY CLEC**



### 2. Properties of a Dial-Up Internet Connection

13. There are several important facts to note about the process of a dial-up Internet connection. First, the communication is carried over a circuit-switched connection[5] until it reaches the ISP's modem and router where the call is turned into a packet-switched transmission and then routed over the Internet to the location of the server being contacted by the customer who originated the communication.[6] Thus, the dial-up connection is part of a single integrated or end-to-end Internet communication or call.

14. Second, it is important to focus on how the information flows in an Internet dial-up connection. For example, suppose a Verizon customer in Virginia, whose ISP is UUNET, wants to get information about the Paris Metro schedule from the Internet. The end user types in the URL characters on the computer keyboard "www.paris.org/Metro" (or accesses that URL through a browser). As the signal from the letters typed on the keyboard passes through the computer, the characters that make up the URL are coded into packets[7] of information that are sent bit-by-bit to the computer modem. The computer modem transforms them into a format that travels efficiently across Verizon's network, as shown above in Figure 2, to the WorldCom local exchange network and to UUNET's packet switched Internet backbone network. At this point, individual packets of information can be routed in many different ways across several different backbones and ISPs, but ultimately the packets arrive on the Paris Metro's web server in France. At this point, the packets are reassembled into a complete communication and the communication "terminates." In response to the request for information sent by the Verizon user, the Paris Metro

[5] A circuit-switched network establishes a fixed-capacity, end-to-end connection that remains dedicated to a specific call during its duration. The traditional plain old telephone service uses circuit switching for analog voice communications. This network is less efficient for data transmission than are more recent designs. See description of packet switching below.

[6] Packet-switching technologies break information into small pieces, called packets, comprised of a number of bytes, assigning each packet identifying characteristics as well as a destination address. The packets traverse the network until they arrive at their destination and are reassembled. Packet-switched networks are designed to efficiently handle data transmission, because they allow multiple data communications to share the same circuit and send data along multiple routes to take advantage of free network capacity.

web server then sends the requested information back to the customer who had originated the call. Of course, as in the calling card example above, a customer may communicate with a number of different web sites during any given session. In each case, the end-to-end communication terminates at the distant web site with which the customer had chosen to communicate.

15. Third, communications over the Internet go from end-to-end with no examination of the contents of the communication at intermediate points along the way—substance is passed across the Internet in an unaltered state. Returning to the Paris Metro site example, while the format of the bits in the packets of information sent by the Verizon customer may be coded, decoded, and translated a number of times as they traverse different parts of the network, the substance is not altered. It reaches the terminating point (in this case, the web server in Paris) unchanged.

16. Additional strong support for the view that Internet connections provide end-to-end connectivity is the fact that they support encrypted connections using technologies described by acronyms such as PPTP, Ipsec, and SSL (point-to-point tunneling protocol, Internet Protocol Security, and secure sockets layer, respectively). The information on such encrypted connections flows from the originating computer to the destination computer in a scrambled, or encrypted, form. Not only is it unintelligible to any eavesdropper along the transmission path, but altering even one bit of the transmitted data will cause the altered data be rejected. Such secure connections are often used for commerce over the Internet. People do not want to have their bank codes or credit card numbers transmitted in the open for an eavesdropper to intercept.

17. Microsoft describes the PPTP built into Windows NT and the Microsoft server products saying:

---

[7] A *packet* is a generic term for a bundle of data, usually in binary form, organized in a specific way for transmission.

> The Routing and Remote Access Server (RRAS) add on for Microsoft Windows NT can be used to create virtual private networks (VPNs) across the Internet. VPNs use the PPTP protocol for secure encrypted communication across the Internet. [8]

18. Similarly, in describing some of the security options for the Internet Protocol, the authors of IETF RFC2401 repeatedly refer to *end-to-end* capabilities. They also say,

> The set of security services that IPsec can provide includes access control, connectionless integrity, data origin authentication, rejection of replayed packets (a form of partial sequence integrity), confidentiality (encryption), and limited traffic flow confidentiality. Because these services are provided at the IP layer, they can be used by any higher layer protocol, e.g., TCP, UDP, ICMP, BGP, etc.[9]

19. The technical alternatives that permit use of secure connections over the Internet show that these communications must be end-to-end. The transmitted information is unintelligible at any intermediate point.

20. The nature of an Internet connection can also be shown using software tools operating on a computer connected to the Internet. One such tool, often used to check the function of networks or of network connections, is called traceroute.[10] Traceroute reports on the path between the computer it is running on and another computer on the Internet. The report from traceroute gives information on every Internet switching point from the origin of the connection to the termination. For example, to print out the path from the computer you are using to the computer holding the home page of the Federal Judiciary, the command is "traceroute www.uscourts.gov" or, for Windows users, "tracert www.uscourts.gov."

21. I used a modified version of traceroute that prepares a table and map to illustrate an Internet connection from a user in Virginia to the web server of Travelocity, an Internet travel agency. Figure 3 below shows the result. Data packets flow from the user's computer, with IP Address 10.4.1.131, to the UUNET network. The data packets hop through the UUNET network to the American Airlines network in Fort

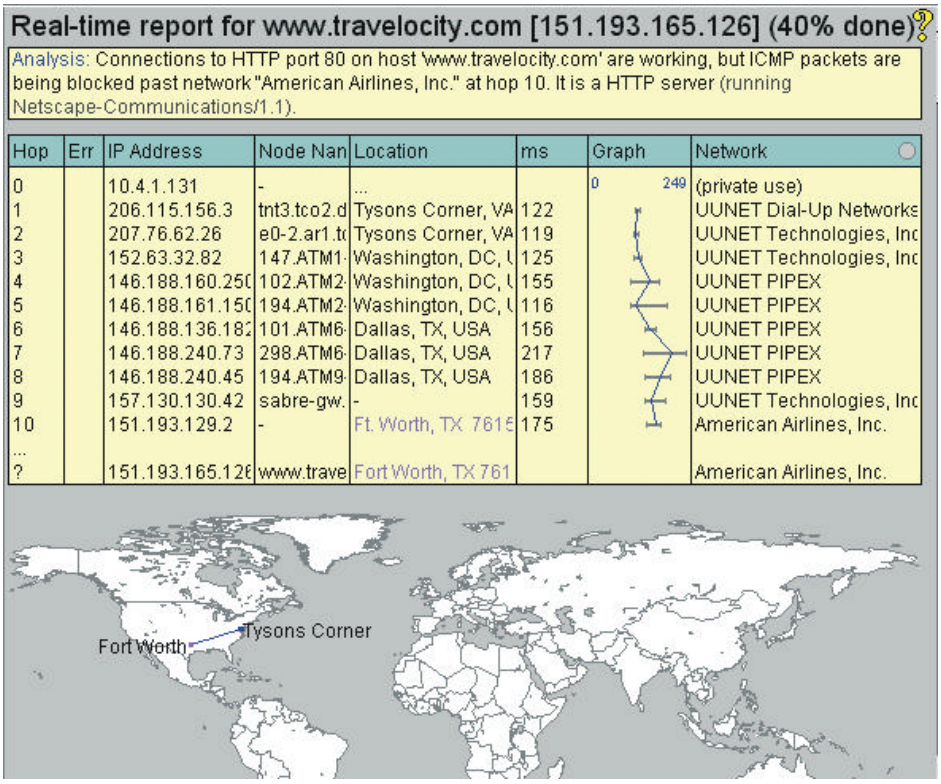
---

[8] http://support.microsoft.com/support/kb/articles/q176/9/24.asp

[9] IETF RFC2401 at http://www.ietf.org/rfc/rfc2401.txt

Worth, Texas, where they are delivered to Travelocity. The UUNET dial-in modem is connected to a WorldCom telephone line in Tysons Corner, Virginia. UUNET, an ISP, is also owned by WorldCom.

**FIGURE 3. THE ROUTE OF AN INTERNET CALL**




[10] The traceroute program is found on most computer systems. The Microsoft Windows version of traceroute is named tracert. For a description and history of traceroute, see http://boardwatch.internet.com/mag/96/dec/bwm38.html.

## V. CONCLUSIONS

22. Like telephone calls, Internet connections pass through several types of intermediate processing. Such intermediate processing cannot obscure the fact that the information flow—the content, the communication—passes unchanged from the originating computer to the destination computer.

I declare under penalty of perjury that the foregoing is true and correct. Executed on July 20, 2000.

**Charles L. Jackson**